Vera C. Rubin Observatory
Systems Engineering

System First Light Definition

Keith Bechtol, Anastasia Alexov, Chuck Claver, Holger Drass, Leanne Guy, Robert Lupton, Kevin Reil, Steve Ritz, Austin Roberts

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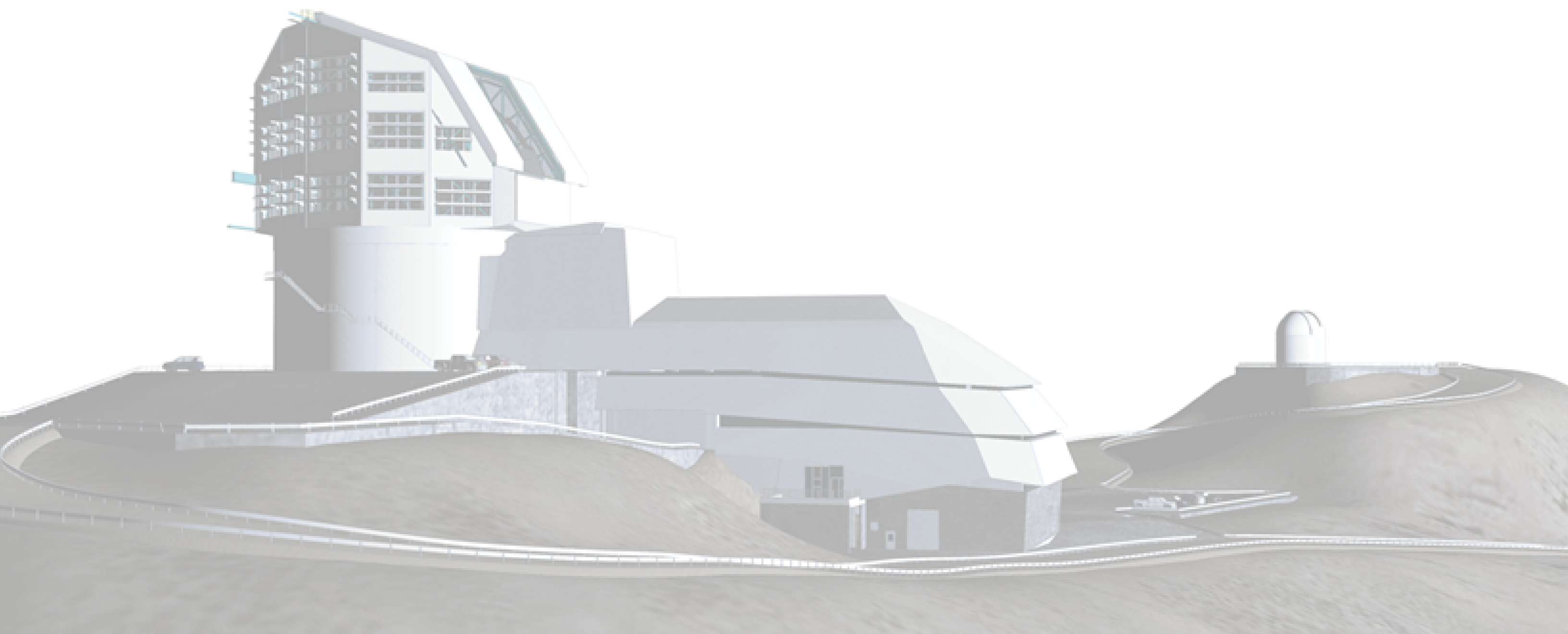

Abstract

System First Light is an intermediate technical milestone between recording the first on-sky images with the LSST Science Camera (LSSTCam) and the start of the 10-year LSST survey. System First Light is defined as the point at which we can routinely acquire science-grade imaging across the full LSSTCam focal plane and have a well understood technical path towards meeting the Construction Completeness criteria. This document provides a technical definition of the System First Light milestone, and describes an example test dataset that could be used to verify that these criteria have been satisfied.

Change Record

Version	Date	Description	Owner name
1	2023-10-30	Initial Release	Keith Bechtol
2	2024-10-24	Update for Construction Closeout Reviews	Keith Bechtol

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System First Light Definition

1 Overview

System First Light is an intermediate technical milestone between recording the first on-sky images with the LSST Science Camera (LSSTCam) and the start of the 10-year LSST survey. System First Light is defined as the point at which we can routinely acquire science-grade imaging across the LSSTCam full focal plane and have a well understood technical path towards meeting the Construction Completeness criteria [SITCOMTN-005]. The System First Light milestone represents

- the retirement of major technical risks to overall system performance (including delivered image quality and system throughput),
- reduced uncertainty on the remaining Construction schedule, and
- an increased emphasis on bulk data collection to support science verification and validation activities leading up to the Construction Closeout Reviews.

Section 2 provides a set of quantitative criteria to define the System First Light milestone, and Section 3 describes an example test dataset.

The System First Light milestone will be used by Rubin Observatory Operations to more accurately gauge the start date of the 10-year LSST survey and to prepare for Early Science, including the Data Previews and start of Alert Production [RTN-011] . System First Light is a widely publicized milestone for external stakeholders (e.g., ls.st/dates), with anticipated celebratory events, media coverage, and release of images to preview the scientific potential of Rubin Observatory (e.g., color coadd images and difference images to illustrate the detection of transient, variable, and/or moving objects).

In current planning, System First Light follows 2-3 months of on-sky engineering activities that begin with LSSTCam First Photon. **LSSTCam First Photon** is defined as the first image of the night sky produced by photons passing through the Rubin optical system and detected by LSSTCam. LSSTCam First Photon is primarily a functional demonstration, whereas SFL includes additional criteria on science performance and fitness for bulk data collection.

2 System First Light Criteria

By the System First Light milestone, we are confident that

1. members of the commissioning team (not necessarily Operations team) are able to observe a set of target fields with airmass ≤ 2 and acquire science images for at least an hour without interruption at a cadence similar to the baseline LSST survey (i.e., ~ 90 visits per hour with each visit corresponding to a standard ~ 30-second total exposure);
2. those data can be characterized with respect to system-level science performance requirements described in LSR [LSE-29] and OSS [LSE-30], associated with the CCR1 and CCR2 phases, related to single-visit image quality in the r band + at least two of the giz bands;
3. those data meet the following specifications for intrinsic system performance to be acceptable for LSST science:
   (a) median system contribution to delivered image quality (adjusted to zenith) less than 0.7 arcseconds across the full focal plane for r- and i-band images;
   (b) median system throughput integral (atmosphere removed or using a standard atmosphere) known to within 10% uncertainty to meet minimum specifications defined in the SRD (expressed as image depth for point sources as in Table 6) converted to instrumental zeropoints [SMTN-002];
   (c) performance of the LSSTCam as installed on the TMA is consistent with expectations based on acceptance testing at SLAC and re-verification on Level 3, and consistent with supporting LSR requirements (e.g., system read noise, usable pixel fraction, dynamic range);
4. system telemetry, raw and basic ISR-corrected images, as well as diagnostics for single-visit science performance sampled at multiple locations on the focal plane are visible to observers on the summit within 5 minutes of acquiring the visits;
5. following automated data transfer and ingest at USDF, the data management system is functionally capable of both building a 3-band color coadd image and producing difference images from these data that have sufficient information content to support creation of “press-ready” images;

6. there exists a well understood technical path towards satisfying the Construction Completeness criteria [SITCOMTN-005] with minimal technical or schedule risks, including meeting all performance requirements in the SRD at their minimum specifications or better during the LSST 10-year survey.

In order to achieve the milestone, the commissioning team should have reasonable expectation that the criteria above can be met on any given night, for example, based on three or more consecutive nights of stable performance when observing fields at a range of airmass from 1.0 to 2.0. This level of routine functional and science performance, with acceptable observing efficiency, is needed to support bulk data collection to complete commissioning science verification and validation, e.g., the Science Validation survey.

As part of establishing a well understood technical path towards satisfying the Construction Completeness criteria, at least a subset of r- and i-band visits prior to System First Light (spanning a range of airmass from 1.0 to 2.0) should have system contribution to delivered image quality (adjusted to zenith) less than 0.4 arcseconds across the full focal plane to demonstrate that the as-built hardware and software is *capable* of meeting minimum SRD specifications with appropriate control of the AOS, telescope tracking, dome environment, etc., even if this level of performance is not yet *routinely* achieved at the time of System First Light.

The commissioning plan includes a period of system optimization following SLF that is intended to enhance the stability of the system across a range of observing conditions. For the baseline AOS commissioning plan, we expect that validation of the open-loop (look-up table) and closed-loop systems considering the full set of degrees of freedom can utilize the same set of imaging data collected for the science validation survey (except for a brief period of full array mode out-of-focus data to validate the sensitivity matrix).

3 Example Test Dataset to Support System First Light Milestone

3.1 Minimal Dataset

The criteria listed in Section 2 could be verified with the following example “mimimal” test dataset that could be acquired in roughly an hour of on-sky observations (roughly ~ 90 visits, assuming each visit is ~ 40 seconds for integration, readout, and slew) taken on each of three nights. Take repeated observations of a field (e.g., 30 visits in each of the gri bands) with translational dithers ranging from detector-scale up to focal-plane scale so that individual stars are measured on multiple detectors across the focal plane. The number of visits is chosen to approximate the number of overlapping visits that would be acquired during the first year of the LSST Wide-Fast-Deep survey over a region of ~ 10 square degrees. For a typical high Galactic latitude density of ~ 1 Gaia reference star per square arcminute, this region would include measurements of roughly $\sim 3 \times 10^4$ high SNR stars, and ~ 1 million individual measurements of the PSF sampled across the focal plane. For the minimal dataset, the observing epochs spread across multiple nights do not necessarily need to cover the same field, but should span a range of airmass, e.g., 1.0, 1.4, and 2.0, to demonstrate stable performance.

3.2 Baseline Dataset

In practice, we plan that the minimal set of observations above would be acquired as part of a larger "dense dithered star field" science program with multiple fields, observed in at least 5 bands, in multiple epochs spread across several nights. For example, 4 fields × 30 visits × 5 bands × 3 epochs with 600 visits per night could be acquired in 3 full nights of observing, or 6 half-nights of observing. The epochs and fields should be selected to sample observations at a range of airmass, e.g., 1.0, 1.4, and 2.0, with the repeated epochs for a given field scheduled on distinct nights to sample a larger time baseline. By slewing between multiple fields spanning a range of telescope elevations within a single night, we could verify the AOS performance to maintain the figure of optical surfaces for gravitational forces at a range of telescope orientations. 30 visits of the same field in the same band within a single epoch is desireable to achieve stable environmental conditions and isolate effects related to the instrumental calibration (e.g., illumination correction, camera distortion model). Scheduling multiple epochs of the same fields allows for tests of difference imaging and characterization of performance across a range of environmental conditions.

The larger "baseline" dataset would enable multiple science verification studies, including

- determination of illumination correction, photometric repeatability, and chromatic part of instrumental throughput (same star through multiple detectors),
- determination of camera distortion model, astrometric repeatability, relationship between DCR and chromatic PSF, and
- initial testing of coaddition and difference imaging.

A subset of these images could form the basis of Data Preview 1 [RTN-011].

A References

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B Acronyms

Acronym	Description
AOS	Active Optics System
DCR	Differential Chromatic Refraction
ISR	Instrument Signal Removal
LSE	LSST Systems Engineering (Document Handle)
LSR	LSST System Requirements; LSE-29

LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
OSS	Observatory System Specifications; LSE-30
PSF	Point Spread Function
RTN	Rubin Technical Note
SE	System Engineering
SLAC	SLAC National Accelerator Laboratory
SNR	Signal to Noise Ratio
SRD	LSST Science Requirements; LPM-17
TMA	Telescope Mount Assembly
USDF	United States Data Facility